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TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS.

SPECIAL MEETING, APRIL 14TH, 1888.

SUBJECT:

Maximum Efficiency of Incandescent Lamps.

BY JOHN W. HOWELL.

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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

VOL. V. New York, May, 1888. No. 8.

SECRETARY'S BULLETIN.

At the regular monthly meetings of Council held April 3d and May 1st, the following named gentlemen were elected to associate membership in the American Institute of Electrical Engineers, their applications having been properly endorsed:

Lewis Searing, 212 West 130th St., New York.
A. E. Kennelly, Edison's Laboratory, Orange, N. J.

The following associate members were, upon recommendation of the Board of Examiners, transferred to full membership:

C. Wellman Parks, Troy, N. Y.
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Prof. W. D. Marks, Philadelphia, Pa.
Gustav Pfannkuche, Cleveland, Ohio.
Sir David Salomons, Tunbridge Wells, Eng.
Montgomery Waddell, Schenectady, N. Y.

The Annual meeting of the Institute, for the election of officers for the ensuing year, and the transaction of other business, is announced to be held at the House of the American Society of Civil Engineers, 127 East 23d St., New York city, on Tuesday Evening, May 15th, at 8 o'clock. The terms of the following officers and members of the Council expire by limitation in accordance with the rules:—T. C. Martin, President; Dr. Norvin Green, Prof. Elihu Thomson and George C. Maynard, Vice-Presidents

Charles L. Buckingham, Prof. B. F. Thomas, David Brooks and Edward P. Thompson, Managers; George M. Phelps, Jr., Treasurer, and Ralph W. Pope, Secretary. Prof. Elihu Thomson, Vice-President, and Edward P. Thompson, Manager, having been elected by Council to fill out unexpired terms, are eligible for re-election.

The general meeting for the reading and discussion of professional papers convenes at the same place, on Wednesday, May 16th, at 10 A.M. The following papers are to be read:

"*On a new system of Alternate Current Motors and Transformers*," by MR. NIKOLA TESLA.

"*The Possibilities and Limitations of Chemical Generators of Electricity*," by MR. FRANCIS B. CROCKER.

"*Underground Electrical Systems in Europe and America*," by PROF. G. W. PLYMPTON, of the Brooklyn Subway Board.

"*On Compensated Resistance Standards*," and

"*On Prof. Moler's Swinging Arm Galvanometer*," by PROF. EDWARD L. NICHOLS, of Cornell University.

"*The Patent Court and Uniformity in Patent Practice*," by MR. GEORGE H. STOCKBRIDGE.

"*Protection of the Human Body from Dangerous Currents*," by MR. P. B. DELANY.

Mr. Emile Berliner, of Washington, D. C., member of the Institute, has devised an apparatus which he calls a "Molecularium," and by means of which, adopting the theory of molecular vibration, he explains and illustrates a large variety of electrical phenomena, including those connected with static charge and discharge, voltaic current, heat, etc. Mr. Berliner has kindly presented to the Institute a model of this apparatus, which will be exhibited at the meeting, and upon which the inventor invites discussion.

The office and reading room of the Institute, Room 30, Temple Court, No. 5 Beekman Street, is now ready for the accommodation of visitors. All of the leading electrical and mechanical periodicals in the English language will be found on file.

A paper read before the American Institute of Electrical Engineers, April 10th, 1888.

THE MAXIMUM EFFICIENCY OF INCANDESCENT LAMPS.

By John W. Howell.

The word efficiency, when applied to an incandescent lamp, is used to designate the amount of energy required by the lamp for the production of a given amount of light; thus we say that a given lamp has an efficiency of three watts per candle, at sixteen candles, meaning, that to produce an illumination of sixteen candles we must supply the lamp with forty-eight watts.

The word efficiency, when applied to a prime mover or to any piece of apparatus that changes energy from one form to another, or which transmits or utilizes energy, has a well-defined meaning, and is used to represent the ratio of the energy of the useful effect produced by the apparatus, to the energy necessarily supplied to the apparatus to enable it to produce that effect.

An incandescent lamp transforms electrical energy into heat and light, so the use of the word efficiency to denote the watts per candle required by the lamp is not a proper one. To denote properly the efficiency of an incandescent lamp we must be able to separate the energy of the light produced by it from the energy of the heat produced. Then the ratio of the energy of the light to the electrical energy required by the lamp will be a correct expression for the efficiency of the lamp, and we will have to find some other word to designate the watts per candle. In this paper the word efficiency is used in its ordinary improper sense to denote the watts per candle required by a lamp when producing a given amount of light.

The efficiency of a lamp varies with its candle power. The curve, Fig. 1, shows the rate of this variation for a particular lamp. At 5 candles this lamp has an efficiency of 6.7 watts per

candle, at 10 candles it is 4.2 watts per candle, and at 20 candles it is 2.66 watts per candle.

Any statement regarding the efficiency of a lamp must therefore, be accompanied by a statement of the candle power at which it has the stated efficiency; without this it is meaningless. There is nothing in an incandescent lamp itself that fixes its proper

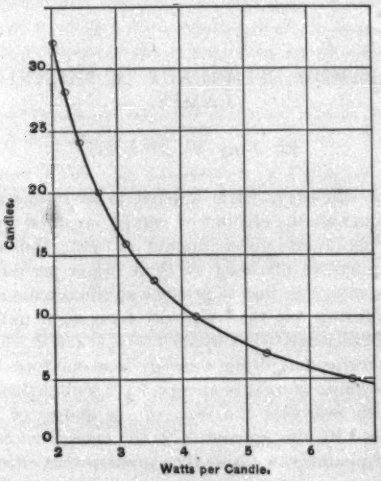

Fig. 1.

efficiency or in any way indicates what it is. The lamp from which the curve, Fig. 1, was determined has, within the limits of the curve, any efficiency between 2 and 7 watts per candle. Thus, by simply changing the candle power of the lamp, we can operate it at any efficiency we choose, and get as much or as little light per watt as we choose.

In commercial practice the candle power of lamps is always marked on them and their efficiency at this candle power is stated; but even this is not a proper index to the value of the lamp or to its proper efficiency. Experience has shown that lamps are almost universally run above their normal rating; lamps rated at 4.5 watts per candle are usually run at from 3.5 to 4 watts per candle, and in order to make lamps that will stand

the strain of being run above their rated capacity, it is necessary to rate them considerably below the efficiency at which they will give the best results under ordinary circumstances.

Lamps have been made and sold in England which have a very high rated efficiency, but parties buying these lamps are told that they will get very much more satisfactory results if they run the lamp *below their rated capacity.* So we see that some lamps are rated above their capacity and some are rated below, and the rated efficiency of a lamp is not always the best efficiency at which to run it. How then, are we to determine the efficiency at which a lamp will give the best results? It is this question which I will attempt to answer.

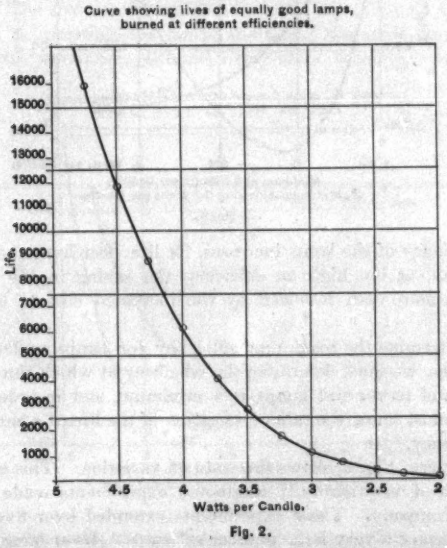

Fig. 2.

The term "maximum efficiency" of a lamp, as used in the title of this paper, does not mean the highest efficiency at which a lamp can be operated, but the efficiency at which the best results are produced by the lamp: or more accurately, *the efficiency at which the cost of operating the lamp is a minimum.*

Taken in this latter sense, the maximum efficiency of a lamp is not its highest efficiency. As we increase the candle power of a lamp its efficiency increases; consequently, by running the lamp high enough we can make its efficiency so high that very little power is required to produce a given amount of light, and the cost of power to produce the light is very small. But, while

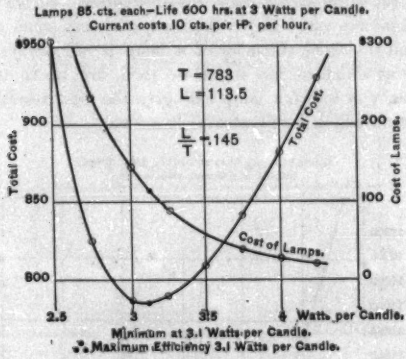

Fig. 2.

the efficiency of the lamp increases, its life decreases, and if we run a lamp at too high an efficiency the saving in the cost of power is more than balanced by the increased cost of lamp renewals.

To determine the maximum efficiency for lamps under given conditions, we must determine the efficiency at which the sum of the costs of power and lamps is a minimum, and in order to do this we must know the rate of variation of the life of a lamp with its efficiency.

The curve, Fig. 2, shows this rate of variation. This curve is the result of very carefully conducted experiments made by the Edison company. These experiments extended over five years and consumed a very large number of lamps. Its accuracy when applied to Edison lamps is beyond question; but our experiments with lamps having an artificial surface on the carbon, or "flashed" lamps as they are called, show that their rate of variation of life and efficiency follows a different curve.

This curve does not apply to individual lamps. If we take

two Edison lamps and burn them at different efficiencies, their lives for these efficiencies will probably not be such as indicated by the curve, nor will they be proportioned to these indicated lives. But if we take one hundred lamps and burn them at one efficiency, and another hundred equally good lamps and burn them at another efficiency, the average lives of the two sets will be proportional to the lives indicated by the curve for these two efficiencies.

In order to determine at what efficiency the cost of operating lamps of a given quality under given conditions is a minimum we must calculate what this cost is at different efficiencies. To do this we consider the total cost of operating the lamps to be made up of two parts, viz., the cost of the *current* and the cost of the *lamps*. The cost of the current is made up of every expense incurred in operating the lamps, including materials consumed, labor, taxes, insurance, rent and every other expense incurred in

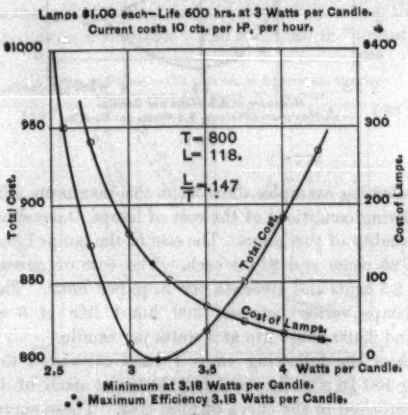

Fig. 4.

operating the plant, except the cost of lamps. The cost of the lamps is an item by itself, and is the amount which the lamp has cost when it is put in use. This is a natural division of the total cost of operating a plant, since to produce light by incandescence all that is necessary is a lamp and current to operate it.

If, in any case, we know the cost of the current required to

operate the lamps, the cost of the lamps, the quality of the lamps —that is, the life they will give when burned at a given efficiency—and the rate of variation of their life with efficiency, we can then calculate at what efficiency the cost of operating the lamps is a minimum, and this I call the maximum efficiency of those lamps.

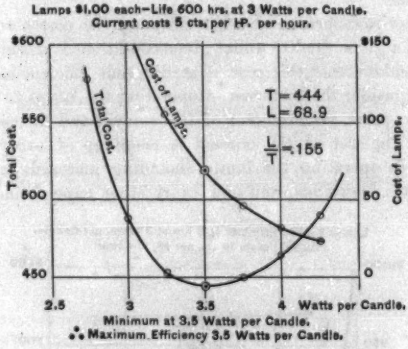

Fig. 5.

The following examples show what this maximum efficiency is under varying conditions of the cost of lamps, the cost of current and the quality of the lamps. The cost of the lamps I have varied between 25 cents and $1.00 each. The cost of current varies between 2.5 cents and 10 cents per h. p. per hour. The quality of the lamps varies between 300 hours life at 3 watts per candle, and 2,400 hours life at 3 watts per candle.

In each of the following cases I have calculated the cost of operating 100 16 c. p. lamps 1,000 hours, at each of the efficiencies comprised in the curve of total cost. These curves do not show the cost of running the same lamps at different efficiencies, but the cost of running equally good 16 candle lamps of the different efficiencies.

The first case we will consider is shown in the diagram Fig. 3. In this case the lamps are assumed to cost 85 cents each and to have a life of 600 hours at 3 watts per candle. The current is assumed to cost 10 cents per h. p. hour.

The cost of the current is determined from the following formula:

$$\text{Current cost} = \frac{\text{w. p. c.} \times 16 \times 100 \times 1{,}000 \times \text{cost of ct. per h. p. per hour.}}{746}$$

And the cost of lamps from this formula:

$$\text{Cost of lamps} = \frac{\text{cost of one lamp} \times 100 \times 1{,}000}{\text{Life at given efficiency.}}$$

The curve marked *total cost* shows the total cost of running 100 16 c. p. lamps 1,000 hours, the efficiencies of the lamps varying between 2.5 and 4.25 watts per candle. The efficiencies are shown by the vertical lines, referring to the scale at bottom. The value of the total cost at any point of the curve is shown by the horizontal line through the point, referring to the scale at the left of the diagram.

The lowest point of the curve shows the point where the total cost is lowest. This is the minimum cost of operating these lamps under the given conditions. The mark at the lowest point of

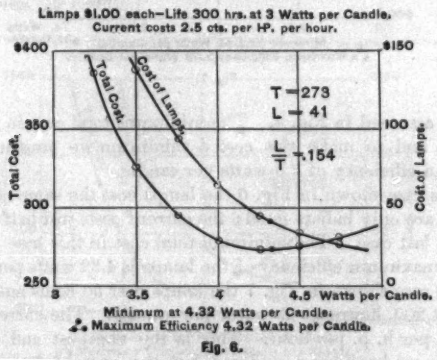

Fig. 6.

the curve shows this minimum cost to be $783, and a vertical line through this point to the scale at bottom of the diagram shows that this total cost is a minimum when lamps having an efficiency of 3.1 watts per candle are used.

Thus the maximum efficiency of these lamps under the conditions assumed is 3.1 watts per candle.

The lamps considered in the case shown in Fig. 4 cost $1.00; all other conditions are the same as in the case shown in Fig. 3. This increases the total cost from $783 to $800, and necessitates using lamps of 3.18 watts per candle instead of 3.1, to make the cost of operating a minimum.

In the case shown in the diagram, Fig. 5, the current costs 5 cents per h. p. per hour; the other conditions are the same as in

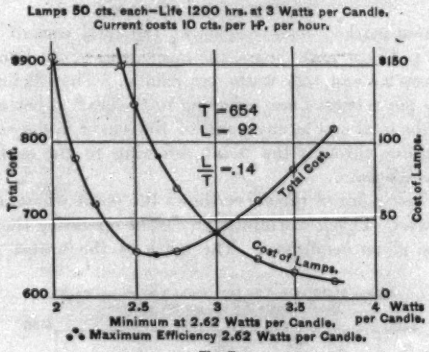

Fig. 7.

the case assumed in Fig. 4. The minimum total cost in this case is $444, and to make this cost a minimum we must use lamps having an efficiency of 3.5 watts per candle.

In this case shown in Fig. 6 the lamps cost the same as in the last, but are only half as good; the current costs just half as much as in the last case. The minimum total cost in this case is $273, and the maximum efficiency of the lamps is 4.32 watts per candle.

In the case shown in Fig. 7 the lamps cost 50 cents and have a life of 1,200 hours at 3 watts per candle. The current costs 10 cents per h. p. per hour. This is the cheapest and also the best lamp we have yet considered, but the current is expensive. In this case the minimum total cost is $654, and the maximum efficiency of the lamp is 2.62 watts per candle. In this case, Fig. 8, the current costs half as much as in the previous case, other conditions being the same. The minimum total cost is reduced from $654 to $362. The maximum efficiency in this case is 2.88 watts per candle. In Fig. 9 the current costs twice as

much as in the previous case and the lamps are only half as good. The minimum total cost is doubled, but the maximum efficiency is the same as in the previous case.

In this case, Fig. 10, the current costs one-half of that assumed in the previous case, other conditions being the same. The minimum total cost is $400, and the maximum efficiency 3.175 watts per candle.

The curve, Fig. 11, illustrates the case of very cheap and very good lamps, with moderate cost of current. The minimum total cost is low, $294, while the lamps are run at the high efficiency of 2.38 watts per candle.

In the case shown in Fig. 12, the cost and quality of the lamps are the same as in the previous case, but the current costs twice as much. This increases the minimum total cost from $294 to $535, and raises the maximum efficiency to 2.14 watts per candle.

In the case, Fig. 13, the cost of lamps and the cost of current are the same as in the case shown in Fig. 11, but the lamps are only half as good. The minimum total cost is increased from $294 to $327, and the maximum efficiency is reduced from 2.38 to 2.62 watts per candle.

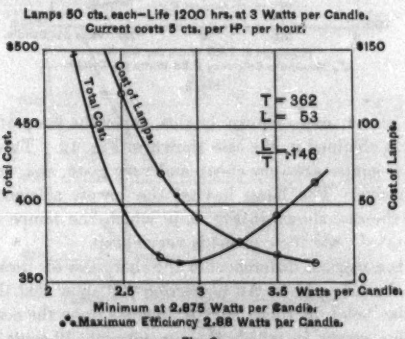

Fig. 8.

The first and plainest inference drawn from these curves is that the maximum efficiency of any given lamp is not a fixed one, but varies with conditions outside the lamp itself. Identical lamps operated under different conditions of cost of current must be burned at different efficiencies to make the cost of operation a

minimum for the production of a given amount of light. In order to determine the maximum efficiency of lamps, therefore, we must know the quality of the lamps referred to some standard, the cost of the lamps to the consumer, and the cost of current under the actual conditions existing at the place where the lamps are to be used.

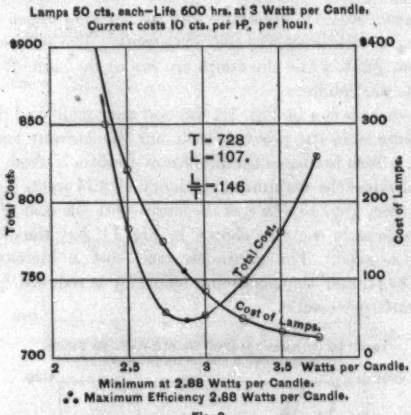

Fig. 9.

In the eleven cases shown in this paper the lamp of highest efficiency is obtained in the case shown in Fig. 12. This is a case where the lamps are very cheap and very good, and current is very expensive. The lamp having the lowest efficiency is obtained in the case shown in Fig. 6, in which the lamps are poor and high-priced and the current is very cheap.

There is a marked difference in the sharpness of these curves at the minimum points. An inspection will show that the sharpness of the bend in these curves depends upon the cost of the current, the curves in which the current costs 10 cents per h. p. per hour being the sharpest. Those, in which the current costs 5 cents, are next, and the one, Fig. 6, in which the current costs only 2½ cents per h. p. per hour, is very flat at the bottom or minimum point. In this comparison Fig. 7 is not considered, as it is drawn on a different scale from the others, and is not as sharp as it should be.

This indicates that the more expensive the power is, the more carefully must the lamp efficiencies be chosen. In Fig. 12, which shows the sharpest curve, a very slight variation in the efficiencies of the lamps makes a very great change in the total cost of operation.

In the case shown in Fig. 6, in which the current is very cheap, we find that a very considerable change in the efficiency of the lamps used makes very little difference in the total cost of operation.

On each of the eleven diagrams two curves are drawn, one showing the total cost of operation, and the other showing the cost of lamps. On each of the curves showing the cost of lamps, a point is marked which indicates the cost of the lamps when the total cost is a minimum. The letter T marked on each of the figures denotes the minimum total cost of operating the lamps under the given conditions. The letter L denotes the cost of the lamps when the total cost is a minimum; and the expression $\frac{L}{T}$ denotes the ratio of the cost of lamps when the total cost is a

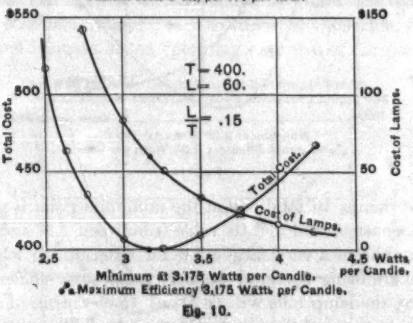

Fig. 10.

minimum, to the minimum total cost. An examination of all these curves shows that while the minimum total cost varies with each of the three quantities—price of lamps, quality of lamps, and cost of current—nevertheless, *the total cost is always a minimum when the cost of lamps is about* 14.5 *or* 15 *per cent. of the total cost of operation.*

This figure varies somewhat in the different examples considered, but the variation seems to follow no law. In Figs. 6 and 12, which show the highest and lowest efficiency lamps, the figures are 15.1 per cent. and 15.4 per cent. respectively.

The steepness of the curve showing the cost of lamps, and the difficulty of determining the exact minimum point of a curve which has been drawn by inaccurate methods, makes it difficult to get the cost of lamps accurately when total cost is a minimum. These curves and values are given just as they were determined, and no effort has been made to bring the results into closer agreement, as could readily have been done. I consider the variation shown by these curves to indicate closely enough that this ratio

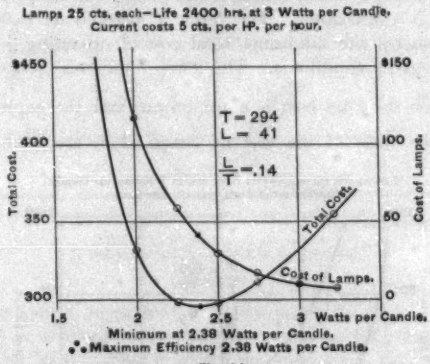

Fig. 11.

of cost of lamps to total cost at the minimum point is nearly, if not quite, constant and that its value is between .145 and .15.

This establishes a very simple law for determining whether or not lamps are being operated at their maximum efficiency; for if they are, the lamp bills will be about 15 per cent. of the total operating expenses of the plant. If the lamp bills are more than 15 per cent. of the total operating expenses the lamps are being burned above their maximum efficiency, and lower efficiency lamps should be obtained. If, on the other hand, the lamp bills are less than 15 per cent. of the total expenses, the lamps are being burned below their maximum efficiency, and higher efficiency lamps would reduce the cost of operating the plant. Where

fuel is high priced, or where other causes operate to make the cost of generating current high, it is specially important to use lamps of the maximum efficiency, for we have seen from the

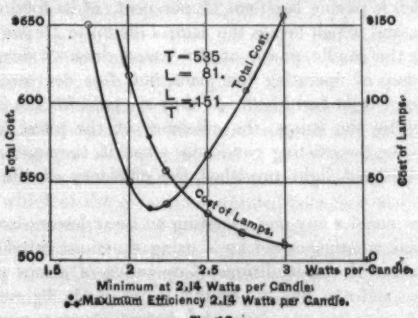

Fig. 12.

above curves that where the cost of current is high, the use of lamps whose efficiency is a little above or below the maximum efficiency attainable under the conditions of operation, makes a very marked increase in the operating expenses of the plant.

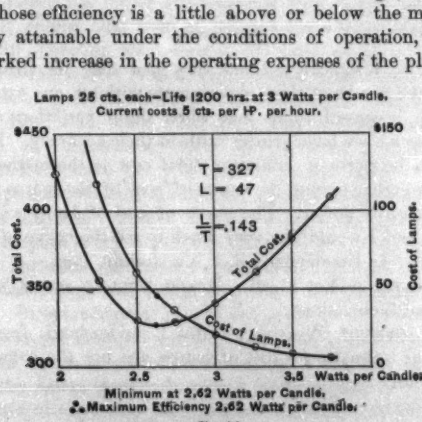

Fig. 13.

If in any plant the lamp bills are only 10 per cent. of the total expenses, then *increasing the efficiency of the lamps by increasing their candle power does not diminish the total cost of*

operating the plant. In order to reduce the total cost, *the lamps must be replaced by lamps of the same candle power but of higher efficiency.* If the efficiency of the lamps is increased by raising their candle power, the cost of operating the plant *per unit of light produced* is reduced, but the total cost is increased. A plant which is paying less than 15 per cent. of its total expenses for lamps, and which brings the lamp bills up to 15 per cent. by increasing the candle power of the lamps, does not decrease the cost per lamp of operating the plant, but *does* decrease the cost per candle of light furnished. If they are paid for the increased light given by the lamps, the efficiency of the plant is made a maximum for the existing conditions; but if they are not paid for the additional light furnished, the efficiency of the plant is reduced.

This law enables any one operating an incandescent lamp plant to determine whether or not he is using the most suitable lamps for his plant. If the conditions of operation of a new plant are all known, and the quality of the lamps made by any lamp maker is known, we can determine before starting what is the most economical lamp to use.

Discussion.

Mr. S. S. Wheeler:—I am very glad that Mr. Howell has given us the results of these experiments without any attempt to alter them, because I think that when slight variations are seen in experiments we have greater faith in their accuracy. I understand that the curve of minimum total cost is the mathematical sum of two other curves, the curve of cost of the lamps and the curve of cost of power. The curve of cost of lamp is there on the chart, and I would like very much to see the curve of cost of electricity. As I understand it, it is a straight line.

Mr. Howell:—Not at all. If you want to see it, you can plot it from these values.

Mr. Townsend Wolcott:—As I understand from this diagram the ordinates for cost of lamps are not the same as for the total cost.

Mr. Howell:—No.

Mr. Wolcott:—So strictly speaking that ought to be entirely below.

Mr. Howell:—Yes, it ought to be. But to do that we would

have to bring the paper away down below, because that cost of lamps comes very nearly down to zero.

MR. WHEELER:—I think it would be an interesting thing to have one of your charts—one of the characteristic ones, with the curve of cost of electricity on it—so as to complete the analysis of the cost. It ought to be a straight line.

MR. HOWELL:—That could be very easily made. (The speaker plotted the curve of electricity on the chart.) It *is* a straight line.

MR. JOSEPH WETZLER:—I would like to ask Mr. Howell if he could base calculations of both central stations and private plants on these diagrams and results, and if so, what the method of differentiation would be for separating the income or expenses of a station which at the same time supplied both power and light—if there be any method of determining that.

MR. HOWELL:—Mathematics does not know the difference between a central station and an isolated plant. Of course, there is no difference. In regard to differentiation, that is a matter of book-keeping entirely. A man has got to know the conditions of his plant in order to tell how much of his power he has got to charge against his motor running and how much against his light. Of course that cost of current includes every expense incurred in operating plant, except the price of lamps. I have got to treat the matter in that way, because what I am after is to get the ratio of cost of lamps to total cost; so I take the cost of lamps by itself, and leave everything else with the cost of current. In an incandescent lamp all you want is a lamp and current and you have got your light. If you know how much your lamps cost and how much your current costs, you have got your total expense. I have charged everything against cost of current, because every expense is incurred in either furnishing lamps or furnishing current to run them. A lamp is a known and definite thing, and everything else I have charged against current. In operating a motor, if you get the cost of current per horse power per hour, all you have got to do is to charge against the lamps the horse power consumed by them, and against the motors the horse power consumed by them, and if you know the amount of electricity used in your motors and in your lamps, the proper proportion of that will be the cost of current in each case.

MR. CHARLES WIRT:—It happens sometimes that power costs so

much you can increase it very cheaply, but if you figure *pro rata* it gives you a larger cost. You are using one hundred ampères, and to get the cost of an ampère you divide the total cost by one hundred; that gives you ten cents an hour. But you can furnish a few additional motors at very slight cost.

MR. HOWELL:—Of course in any case like that, your figuring would not amount to much. I do not suppose any calculations of that kind are of much use unless you apply them on a very large scale. Suppose I know from my records of a station for a whole year my total expenses for that year, the differences between that and my lamp bills will show me the total cost of current. I have also got to know, besides the total expenses, the current produced, the average per month, or the average per year—or differentiate it as much as you like. Of course if you applied that to any given time or any short time, you would find one day very different from another, and you would have to change your lamps every day.

MR. F. B. CROCKER:—I would like to ask Mr. Howell if he thinks those maxima points on the chart should be varied slightly in order to have the lamps break less frequently in deference to the question of human nature. Any one would be willing, I think, to pay a little more for his current rather than have to replace his lamps more frequently, or rather than have one break just as he is reading. It is very annoying. I think almost every customer would like to increase the life of his lamps even though he had to pay more for his current. Do you in practice consider such points as these?

MR. HOWELL:—In any such case the only way you can allow for that on a curve, is to get a money value for that man's inconvenience.

MR. CROCKER:—I do not mean that such a question can be reduced to mathematics; I mean, as a matter of fact, do you modify those results?

MR. HOWELL:—As I say you can make an arbitrary curve or get a money value for the man's inconvenience and charge that against the cost of the lamp. Of course that would make the lamp cost more. The lamp costs not only what you pay for it, but what you have got to pay that man to keep him from growling, and of course that would make the lamp cost more. Or, you can guess at it, if you like.

MR. E. T. BIRDSALL:—I think after the lamp had burned the

maximum number of hours, the customer would rejoice at the breaking of it.

MR. C. O. MAILLOUX:—That suggests another point, which is the fact that the lamps will not remain of normal candle power, but that like all other things in nature they grow old and weary, and they soon reach a point where it is a question whether or not they are darker than the surrounding darkness. I would like to ask Mr. Howell whether the life of the lamp, as it is taken here in these curves, means the time at which they break, or the time at which they become so dark that they no longer give the same candle power, or at least if they are giving the some candle power, it is well known that the watts per candle-power must have increased.

MR. HOWELL:—The life in all lamps is, I think, taken on a new lamp. When any man in the business speaks of an incandescent lamp he means a new one.

MR. MAILLOUX:—It is not new after it has burned 1,600 hours.

MR. HOWELL:—No; you are quite right. But still if you take lamps and consider them when they have burned half their lives, or consider a new one, or consider one two-thirds gone—if you consider them all at the same point you can get a law. You cannot get a law if you consider some new, some old, and some three-quarters old. Of course the easiest point to take, the one of least trouble, is the new lamp.

MR. MAILLOUX:—Then you take the point when the lamp is new.

MR. HOWELL:—Certainly.

MR. MAILLOUX:—And let it burn until it burns out?

MR. HOWELL:—Yes, sir.

MR. MAILLOUX:—By the time it gets old, it is not giving the same candle-power.

MR. HOWELL:—It makes no difference; the law applies just as well. You use the same data on your lamps as you do in determining your law. If you find you want lamps 3.1 c. p. to give maximum efficiency, you take them when new. If you made your curve by taking data of the lamps half old, you would have to do the same thing here. If you start with one point of reckoning, you have to keep it up in all your calculations and experiments.

MR. F. R. UPTON:—A 16 c. p. lamp in practice commercially fills a certain place, and as measured by the makers it can be taken

as a commercial unit, and it is to this that the curves are applied. In this curve (Fig. 2), for example, 3.1 watts per candle is the best efficiency for the commercial man. The current costs ten cents; the lamp, eighty-five cents.

MR. MAILLOUX:—I do not think the significance of what I said is fully understood. It occured to me on looking at the lamp as one of those things which is constantly varying in its light-giving power, that it would react somewhat on that part of the curve which refers to the cost of lamps, because, certainly a lamp of low efficiency would, other things being equal, be preferable, from the fact that it would have a more uniform candle-power and would last longer, probably, before it became dim, and on the other hand a lamp of very high efficiency would soon become dark and would have to be changed. Now it is quite likely that a lamp of high efficiency would have to be changed long before it had broken, and what I meant was whether the cost was to be taken at the time when the customer had got tired of it and had called for a new lamp or whether it included the growling you would allow him to do before being induced to change the lamp.

MR. HOWELL:—In practice you find it universal almost that lamps are taken down before they break. Of course, that affects directly the cost of the lamps, because a central station, furnishing lamps for nothing, gives a man a lamp when it breaks and also when a lamp becomes so black that you have to put a new one in. Of course, a lamp handed to you as being useless, is thrown into the receptacle for broken lamps and is a dead lamp, so it includes lamps only to the point at which they become useless.

MR. UPTON:—The assumption on those tables is six hundred hours. That means, if you get that average light out of the lamp that the curve will hold true. Now the intention of makers of incandescent lamps—I know it is with the Edison Lamp Company—is to make lamps which for six hundred hours will give their full efficiency in candle power. After that there is no guarantee and nothing said about it. We have now a set of new lamps—a hundred of them—which have run four hundred hours, and only four of the lot have broken. It has always been the intention and always the claim that when a lamp is blackened that it should be destroyed. You will notice that the Edison claim has been for a low guarantee, and one reason for that low guarantee is, that the average life of the lamp is not, how long it will stand, but how long it will keep up good commercial efficiency,

and, what happens to the lamp after six hundred hours is of no consequence to this. The assumption is six hundred hours at 3.1 watts per candle-power.

I think Mr. Howell did not call attention to Fig. 2. I think great consideration should be given to it. It represents, as he says, five years experience on the part of the Edison lamp people, and I remember very well that in 1879, at Menlo Park, Mr. Edison spoke a great many times of the great value such a curve would have, and also of the exceeding difficulty of getting such a curve; because you have not only to pick out a large number of lamps from the same lot and test them under normal conditions, watching them closely all the time; but to get a good curve, it requires many months and even years of constantly keeping lamps burning, and this represents the full experience of the Edison Lamp Company, which just before Mr. Howell prepared this paper was carefully gone over, taking in all the lamps which had ever been burned, and I think it is really stated safely, to be within a two per cent. error. Shouldn't you say it was within two per cent?

MR. HOWELL:—I have not given that point any thought. It is practically accurate. That curve, Fig. 2, I do not think could be reproduced on any lamp for ten thousand dollars. What do you think, Mr. Upton?

MR. UPTON:—It has cost more than that to get it.

MR. HOWELL:—I don't think it could be done over again for ten thousand dollars.

MR. UPTON:—It is the most expensive curve in the business. It is a great deal harder to obtain than most people give credit for. It runs into a very difficult experiment. First you have to get your higher values. You cannot have them contemporaneous with the others, because the higher values of lamps will break off quickly; the others will hang on for many weeks and months; and to get your proper values throughout that curve, you must know that your regulations and all your conditions are correct. We commenced that relative value curve at Menlo Park, and it is only recently that we felt certain that that, as shown there expresses the Edison bamboo untreated filament.

MR. WETZLER:—I would like to ask the speaker, if he has evolved the mathematical expression for that law. What formula corresponds to that?

MR. HOWELL:—The law of that curve is a very complex one.

It is not a simple law at all. We have got an expression for it, but it is nothing that you can handle mathematically. I have had a mathematician at work on that for about a week lately to see if he could handle it. I have tried it before and could not handle it mathematically.

MR. WETZLER:—It looks like a hyperbola.

MR. HOWELL:—It is not a hyperbola, or any other curve that has a name. We have got an expression for it that goes all the way across a sheet of paper. It is an exponential law with a constant increment, and the formula is very difficult to get. The graphical solution is very much the easiest.

MR. WETZLER:—As a little digression, I would like to ask if the speaker has ever verified the law for the candle power of the lamp with reference to the current passing through it.

MR. HOWELL:—No, Mr. President, I have not, for the simple reason that current passing through a lamp in incandescent work is something that we do not talk about. We talk about the pressure on the lamp always. I have never verified that with reference to currents, although it is a very simple thing to do. I have all the laws of the lamp referring to candle power, efficiency and all that, but I have never touched the current. We have got all the data but have not worked it out.

MR. WETZLER:—If we assume the resistance of the lamp to remain constant, it evidently is the same function whether we use current or potential.

MR. HOWELL:—We must not assume something that is not so, because the resistance does *not* remain constant. If you were to say that the light of the lamp varied as the sixth power of the current, that would not mean anything to an average user of lamps, because all we know about in practice is pressure, and when you tell a man that the light given by a lamp is the sixth power of the current, it really does not mean anything to him at all, because he does not know how the current varies with pressure. If you tell him the variance between light giving power and pressure, he understands that.

MR. WETZLER:—I merely put it that way because I believe the law was stated at one time in currents, not in potentials.

MR. MAILLOUX:—I would like to ask Mr. Howell if he has any data, or if he knows of observations which have been made tending to show clearly the difference in life of lamps run at the same watts per candle power, using different currents. I sup-

pose that we are all familiar with the statement which went the rounds of the press a year or two ago, to the effect that an alternating current added life to the filament of the lamp; that a lamp run at the same watts per candle-power, at the same efficiency, as Mr. Howell has called it, with an alternating current, would last longer than a lamp run at the same efficiency with a continuous current. If that is true it would certainly be very interesting to have some data by which we could see how great the difference is, because we would naturally expect that the difference must be capable of being differentiated further, and that we would find even different machines capable of showing the difference in the light. Now I may add that my experience with storage batteries has shown that the life of a lamp is undoubtedly increased at the same efficiency—that a lamp running at three watts per candle power, for instance, with storage batteries, will last much longer than a lamp running at the same efficiency from an ordinary current as furnished by a dynamo. How much the difference is I really cannot say; though, as I have said, there seems to be undoubtedly a difference. Now, perhaps Mr. Howell can give us information on that subject which would be very welcome and useful.

Mr. Howell:—To determine the life of any lamp there is one absolute necessity, and that is a constant pressure. During the five years in which that curve was determined, there was always one man who did nothing else but keep the current constant. You can do that with a dynamo, but you cannot do it with storage batteries. I say you cannot—you cannot in practice; and any man who draws inferences as to the life of lamps from a dynamo and from a storage battery, without having done that—well, I do not take much stock in his inferences. I have had a good deal of experience with lamps on storage batteries, and I am perfectly willing to be criticised when I make the statement that the pressure on the storage battery, as ordinarily installed, varies, I think, five times as much as it does on the average dynamo plant, and that the life of lamps on a storage battery plant, as ordinarily installed and handled, is very much lower than it is on the average dynamo plant, due to nothing else than the simple impossibility of keeping their pressure anywhere. I mean that that is a defect in their methods more than anything else. They use their lamps and charge the battery at the same time, and while they have means of keeping their pressure constant, they do not do it.

MR. MAILLOUX:—I wish to observe that I am very sorry Mr. Howell did not get hold of the right battery. Probably that is the reason why Mr. Howell has found such a great difference. It was not the same battery, and it was not handled the same way. We have found that by using suitable precautions and devices, it is possible to secure as constant, if not more constant, electromotive force with a storage battery, as with any other device for producing electricity, so that there should not be any great difference due to that cause. I freely confess that I have had no facilities for making quantitative experiments or determinations by which I could get at the exact value of the difference to which I adverted; but it seems to me that there must be a difference there somewhere, and it would be very interesting to get at what it is.

MR. HOWELL:—The handling of it has got more to do with it than the battery has. It just occurs to me right here that I was sent to investigate the lamps in a storage battery plant. Of course I went into the place as a stranger and asked innocent questions. In this case that I speak of I got the freedom of the plant and went down and talked with the engineer. I said "Those lamps don't look very bright; do you call that a good light?" He says, "No; that isn't any good, but you ought to be here when the engine is running."

MR. MAILLOUX:—When you take into consideration that a storage plant that gives nominally about two volts per cell requires from two and four-tenths to two and one-half volts for charging, and multiply that by fifty cells, you can readily perceive why the light was so much brighter when the engine was running.

MR. HOWELL:—There is no question that the possibilities of the storage battery are very great. For laboratory work, where we want a constant current, there is probably no equal to it for a short time, or probably for any time; but for practical work, as storage batteries are installed commercially, it is very far from being a constant pressure.

MR. FRANKLIN L. POPE:—So far as I know, no accurate experiments have been made to determine the difference in life between lamps run at an equivalent candle-power with an alternating and with a direct current; but I may say, that while I was in England about two years ago, there was some conversation among a number of electrical engineers one evening, in which that subject

was brought up, and—speaking of a plant that had been installed in Whiteley's large establishment at the West End and worked directly by an alternating dynamo—I think it was a Ferranti machine—the assertion was very positively made, that the lamps showed a longer life with an alternating current than with a direct current, and the reason put forward to explain it was, that with a direct current the hot carbon was somewhat in the condition of an electrolyte and was more apt to throw off a deposit and disintegrate than when the current was continually reversed. But I do not know whether there is anything in that or not. I simply give it as the conversation I heard at that time.

MR. HOWELL:—I think an argument drawn from one case or a few cases of that kind is hardly to be depended on, because you take the identical lamps and put them on different plants run from straight or alternating currents you get different results due to different handling. It is the hardest thing that I have ever undertaken to compare the lives of lamps. Now, as showing the difficulty and the misleading effect of the local conditions in a plant, when we first started in the business, we made lamps, of course from ninety to one hundred and ten volts, and on our isolated plants we ran lamps from ninety-five to one hundred, most of them, and those lamps were all made at once. Now, the man who put in our plants and who is in charge of the work, found a good many plants giving good results and using ninety-seven volt lamps. He found ninety-six, ninety-eight and ninety-nine were giving bad results, and he drew the conclusion that the ninety-seven volt lamps were better than ninety-six and ninety-eight. He drew that inference from facts determined from two or three plants at each time. Now, the volts of the lamp had nothing to do with it. The conditions of operating the plant affected the lives in the various cases. If the man who was getting good results from ninety-seven and the man who was getting bad results from ninety-six were to change their lamps, they would get the same as they did before. The lives of lamps are affected by every condition of running. To draw conclusions from a few lamps is misleading.

MR. UPTON:—We had another instance of the finding of the relation of lives of lamps. This came from Shamokin, Pa. By breaking off the tip of a lamp under water, you can fill the lamp, and you will obtain a little bubble there. This man broke the tips of a large number of lamps and concluded the larger the

bubble the longer the life of the lamp. This satisfied him until we showed him that on the size of the opening depended the size of the bubble, and when broken in mercury you cannot see the bubble at all. I think the question of alternating current and straight current in its effect on the life of lamps is an unsettled question and that there is not an authoritative answer to that as yet. All our experiments have so far indicated negative results. The life is the same whether the current be straight or alternating. I do not think there are any experiments as yet proving a material difference between the two, that is, where the conditions are thoroughly watched all through. With alternating currents it is very difficult to indicate the pressure.

MR. F. L. POPE:—I quite agree with Mr. Howell that deductions drawn from a few experiments have no value whatever, and I merely mention it as current talk without taking very much stock in it myself. I should not be at all surprised to find, after a proper investigation had been made, that there was little or no difference.

MR. MAILLOUX:—In the early experiments in car lighting, that were conducted by a company here with storage batteries, they very quickly found it necessary to increase the efficiency of the lamp, otherwise there would not be enough energy to make a round trip. At that time the lamps of two and one-half watts per candle-power were not in commercial use. They were not to be had. So this company applied to the Edison people to have some lamps made of two and one-half watts. The Edison company replied that they could make lamps of any efficiency and that they would be glad to make them, but that they would not guarantee any life at all. I was not connected with the company at the time, but I understand that is the way it happened;—they took the lamps and concluded that they would risk it; let them break. They thought that lamps were cheaper than current, especially when you have got to take current from storage batteries; and they put the lamps on. I know that some of those lamps were in use for over three months. There may be some of them still in use, and they are running very satisfactorily, and they not only get full pressure, but they sometimes get more when the battery is overcharged and care is not taken to maintain constant electromotive force. The lamps now used in car lighting are all of two and a half watts or less. Whether that throws any light on the subject under those conditions I cannot say. It may be that the

Edison company did not consider it wise for them to use that same lamp at such a high efficiency.

MR. BIRDSALL:—As regards the life of a lamp when running above voltage, I have found plants which have run the old Edison lamp—a ninety-four volt lamp. They ran at one hundred and fifteen volts, and then they would give nine hundred hours life, and the men did not appear to think that there was very much lamp breakage even for that excess of voltage.

MR. UPTON:—As to these curves which have been put on the board to-night, Mr. Howell asked me whether we should publish these results. We discussed it and concluded it was better to publish what we could about the relations between economies and lives of lamps. The time, we concluded, had come, when the public should fully recognize that the mere claim of giving 2 watts or 2½ watts or 3 watts or whatever it is per candle, means nothing, until these claims have been verified by long practice, and we know in the lamp business that no lamps can be put upon the market, unless they have a large margin over the laboratory test, as otherwise your complaints and troubles will more than counterbalance the gain, and these curves that Mr. Howell has presented here, are based, I think, safely on commercial practice, and we have chosen in this case about 3 watts per candle as our normal, and we recommend it as embodying our experience and the recommendation of the Edison Company for the best commercial practice.

MR. MAILLOUX:—I would like to ask Mr. Howell if the light tests are made with a lamp running continuously; that is to say, is the current interrupted over night?

MR. HOWELL:—Yes, sir; we shut down at six o'clock.

MR. C. J. FIELD:—With regard to the new lamp mentioned there (the 3.1 watts lamp) I would state that it has been in use now since the first of last September. It is running, as a rule, 3 to 5 volts above pressure, and is run under all sorts of conditions. It has been shown on careful investigation by a man detailed especially for that purpose, that the new lamps are giving an average of over 1,000 hours' life in commercial use, and in some cases from 1,500 to 1,800 hours, and many agents are requesting the company to raise the guarantee to 1,000 hours.

MR. F. L. POPE:—Mr. President, there is a great deal of uncertainty in the photometric measurements of lamps. Two or three years ago we heard a great deal about the remarkably effi-

cient incandescent lamps that were produced in England, and a gentleman of my acquaintance procured some and undertook a photometric investigation of them, but he was not able to get as good results as they had obtained in England. As it happened, I was over there not long after and made some inquiries, and found the trouble to be in the system of measurement. My friend had measured them all around the horizontal circle, while the English photometers had taken merely the highest point. They had measured them at but one angle, and that was the way they obtained the results which were claimed.

THE PRESIDENT:—We have reached the usual hour of adjournment. Should there be no further discussion on this very interesting and valuable paper, a motion to adjourn will be in order.

I think we all feel greatly indebted to Mr. Howell for the trouble he has taken in preparing this paper, and also for the fact, that he has been enabled, and I may say allowed, to present to us information which has been accumulated at so great cost and expense and which must be of the utmost benefit to all who are engaged in the business and profession of incandescent lighting in this country and abroad. I am sure that these results will be noted with interest not only in America, but throughout the world, wherever incandescent lamps are used.

The knowledge of the fact of Mr. Howell's constant application to the study of the incandescent lamp for the last five years, and probably longer, was to my anticipations a sufficient guarantee that his paper would be of great value. We expected much from him, but he has given us even more.

Adjourned.

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Telephony and Telegraphy in the Tropics. *Lond. Elec. Rev.*, March 2, p. 220.

The Use of the Telephone in Europe. *Elec. World*, March 24, p. 155.

The Rise and Progress of Telephony in the United Kingdom. (Contin'd.) *Lond. Elecn.*, March 2, p. 437; March 23. p. 537.

Overhead Circuits for Long-Distance Telephony. (Ill.) M. J. Banneux. (Chief Eng. of the Belgian Telegraphs.) *Lond. Elecn.*, March 2, p. 447; *West. Elecn.*, March 31, p. 164; *Elec. World*, March 31, p. 161.

Long-Distance Telephony: The Influence of Self-Induction. *Lond. Elecn.*, March 9, p. 480. Abs. *Jour. Soc. Tel., Engrs. and Elecns*, No. 70. Abs. from paper by M. Vaschy. *La Lum. Elec.*, Vol. xxv., No. 27, p. p. 18-20; No. 30, p. p. 165-170; No. 32, p. p. 264-70, 1887.

Long-Distance Telephoning. (Ill.) *N. Y. Elec. Rev.*, March 17, p. 1. Shows and describes desk set of instruments and a portion of pole line.

Practical Telephony. (Ill.) Part VI. Thos. D. Lockwood. *West. Elecn.*, March 3, p. 112. Part VII., March 24, p. 146.

ELECTRIC LIGHT.

Electric Lighting in the Asiatic Empires. *Chicago Herald; Sci. Am.*, March 3, p. 133.

The Hydraulic Power and Electric Light Installations at Hamburg. *Indust.*, March 23, p. 302.

Train Lighting in Germany. *Indust.*, March 2, p. 227.

Electric Light in Scandinavia. (Note.) *Eng.*, March 23, p. 298.

Illuminating the Aurora Borealis. (Ill.) *Elec. World*, March 17, p. 138. Description of Thomson-Houston station at Hernosand, Sweden; the most northerly in Europe.

Electric Lighting in Paris. *Elec. World*, March 10, p. 126.

Electric Lighting in Mexico *Boston Herald; Elec. World*, March 10, p. 126.

Electric Lighting in Russia. (Note.) *Money; Lond. Elec. Rev.*, March 23, p. 319.

A Central Electric Lighting Station at Amsterdam. *Lond. Elecn.*, March 23, p. 537.

Notes from Brussels: The Lighting of the Exhibition. *Lond. Elecn.*, March 2, p. 450; *Lond. Elec. Engr.*, March 2, p. 202.

The Electric Lighting of the Savoy Theatre. *Lond. Elecn.*, March 2, p. 440.

The Electric Light Convention at Pittsburgh. *Elec. World.*, March 3, p. 101; *Lond. Elecn.*, March 9, p. 478; *West. Elecn.*, March 3, p. 114; *Md. Lt. & Ht.*, March 1, pp. 177–179; *N. Y. Elec Engr.*, March, p. 81; *N. Y. Elec. Rev.*, March 3, p. 1; *Science*, March 9, p. 111.

Seventh Meeting of the National Electric Light Association. (President's Address.) *Elec. World*, March 3, p. 102; *N. Y. Elec. Engr.*, March, p. 124.

Electric Street Lighting. *Indust.*, March 2, p. 220.

Disc Arc Lamps. (Note.) *Eng.*, March 23, p. 297.

Fire Office Rules. *Eng.*, March 30, p. 315.

Rules and Requirements of the New England Insurance Exchange for Electric Lighting by the Arc System *Md. Lt. & Ht.*, March 29, p. 358; *N. Y. Elec. Rev.*, March 31, p. 8.
(Adopted March 1, 1888, and superseding all previous rules.)

The Relation of Electric Lighting to Fire Insurance. S. E. Barton, Nat. Elec. Lt. Assn. *Elec. World*, March 3, p. 111; *Md. Lt. & Ht.*, March 1, p. 216; *N. Y. Elec. Engr.*, March, p. 95; *N. Y. Elec. Rev.*, March 3, p. 14.

What Constitutes a Good Carbon Point. G. W. Parker, Nat. Elec. Lt. Assn. *Elec. World*, March 3, p. 112; *Lond. Elecn.*, March 9, p. 479; *Md. Lt. & Ht.*, March 1, p. 218; *N. Y. Elec. Engr.*, March, p. 111; *N. Y. Elec. Rev.*, March 3, p. 14; *Lond. Elec. Engr.*, March 30, p. 303.

Insulation and Installation of Wires and Construction of Plant. Prof. Elihu Thomson, Nat. Elec. Lt. Assn. *Elec. World*, March 3, p. 102; *Lond. Elec. Rev.*, March 23, p. 313; *Md. Lt. & Ht.*, March 1, p. 183; *N. Y. Elec. Engr.*, March, p. 90; *Lond. Elec. Engr.*, March 9, p. 226,

Thomson-Houston Electric Company. (Ill.) *Md. Lt. & Ht.*, March 1, p. 247.

The Thomson-Houston Plant in Lynn, Mass. *N. Y. Elec. Rev.*, March 3, p. 13.

Origin and Growth of the Thomson-Houston Company. *Md. Lt. & Ht.; West. Elecn.*, March 3, p. 116.

Hawkeye Electric Company. (Ill.) *West. Elecn.*, March 31, p. 159. (System of arc and incandescent lighting.)

Electric Light for Fifth Avenue Stages. *N. Y. Elec. Rev.*, March 10, p. 8.

A Most Creditable Electric Light Installation. *N. Y. Elec. Rev.*, March 10, p. 1.
U. S. Court House and Post Office, Philadelphia.

Electricity in the Hotel Ponce de Leon, St. Augustine. H. B. Rockwood. *Sci. Am.*, March 31, p. 193.
Power is obtained from driven wells, for a large Edison installation.

Minor Phenomena of the Incandescent Electric Lamp. *Sci. Am*, March 10, p. 144; *Lond. Elecn.*, March 23, p. 544.

The Edison Philadelphia Plant. (Ill.) *N. Y. Elec. Rev.*, March 17, p. 8. (Views of new station.)

The Electric Light Plant in the Equitable Building, N. Y. (Ill.) *N. Y. Elec. Rev.*, March 17, p. 6.
The largest isolated incandescent plant in the world; the building is wired for between 6000 and 7000 lights, and there are seven 600-light dynamos with a common field exciter.

The Electric Light for Elevated Cars. *N. Y. Sun; N. Y. Elec. Rev.*, March 17, p. 2.

On the Cost of Central Station Lighting. R. E. Crompton. *Indust.*, March 16, p. 276. (Corr.) C. W. S. Crawley. J. K. D. Mackenzie. March 23, p. 300.
See *Indust.*, p. 598, Vol. III.

Central Station Lighting by Storage Batteries. *Indust.*, March 2, p. 220; *N. Y. Elec. Rev.*, March 24, p. 10.

Artistic Electric Lighting. H. Swan. City and Guilds of London Inst., Old Students Meeting. *Lond. Elec. Engr.*, March 9, p. 224; *West. Elecn.*, March 31, p. 163.

Portable Reading Lamp. *Lond. Elec. Engr.*, March 2, p. 211.

The Seel Incandescent Lamp. *West. Elecn.*, March 3, p. 112.

An Electrically Lighted Coupé. *West. Elecn.*, March 3, p. 109.

Another Lamp Freak. (Ill.) *Elec World*, March 31, p. 162.
An Edison "municipal" lamp showing two well marked distentions of the globe, caused by failure of the filament. In the case previously noted, the glass, on becoming soft, had yielded to the pressure of the outer air and had been forced in.

Incandescent Lamps. *L'Electricien; Elec. World*, March 24, p. 150.

Why do Incandescent Lamps Blacken? Hosea E. Husted. *Elec. World*, March 17, p. 138.

How to Determine the Nature of the Current in Incandescent Lighting. *Lond. Elecn.; Elec. World*, March 17, p 135.

Electric Safety Lamps. *Elec. World*, March 10, p. 126.

The Heisler Series Incandescent System. (Ill.) *Elec. World*, March 10, p. 123.

Plant at Matteawan, N. Y., with one machine furnishing 190 lights of 20 and 30 c. p. on 18 miles of circuits, No. 8 B. & S. wire; all lamps in series.

New Lampholder. (Note.) *Lond. Elec. Rev.*, March 30, p. 346.

The "Municipal" Lamp. (Note.) *Lond. Elec. Rev.*, March 9, p. 263.

Note on the Efficiency of Incandescent Lamps with Direct and Alternating Currents. W. E. Ayrton & J. Perry, Phys. Soc *Lond. Elecn.*, March 2, p. 454; *Lond. Elec. Rev.*, March 9, p. 277; *Eng.*, March 2, p. 223; *Eng.*, March 16, p. 272; *Indust.*, March 2, p. 214.

Efficiency of Incandescent Lamps and Electric Traction. (Corr.) W. E. Ayrton. *Lond. Elecn.*, March 9, p. 481.

Vesey's Electrical Odontoscope. (Ill.) *Lond. Elecn.*, March 2, p. 438

The Elements of Electric Lighting. Philip Atkinson. No. XXXI. *West. Elecn.*, March 3. p. 115; No. XXXII., March 10, p. 124; No. XXXIII., March 17, p. 134.

Lane-Fox Carbons. Cruto Carbons. Swan Carbons. Weston Carbons. Construction of Electric Lamp.

Electric Lighting. (Ed.) *Lond. Elec. Rev.*, March 9, p. 249.

The Electric Lighting Act. (1882) Amendment Bill. *Lond. Elecn.*, March 9, p. 484; *Lond. Elec. Rev.*, March 9, p. 259; *Lond. Elec. Engr.*, March 9, p. 235.

The Electric Light Act. (Note.) *Lond. Elec. Rev.*, March 30, p. 343. *Indust.*, March 2, p. 246.

The Electric Light and our Eyesight. *Rev. Int. de L'Electricité; Md. Lt. & Ht.*, March 22, p. 332.

Contracts for Electric Light Wiring. *Lond. Elec. Rev.; Elec. World*, March 17, p. 135.

The Accumulation of Dust on Electric Light Wires. Geo. A. Nellis. *Elec. World*, March 10, p. 122.

The statement is made that the wires indoor carrying alternating current do not blacken or accumulate dust, whereas those carrying direct current always do.

Safety Fuses for Electric Light Circuits. *Elec. World*, March 10, p. 122.

Safety Fuses. (Corr.) "Electrophile." R. Fred. Yorke. *Lond. Elec. Rev.*, March 2, p. 246.

Putting up Internal Work. G. L. Addenbrooke. *Lond. Elec. Rev.*, March 30, p. 334.

Insulation for Conductors for Internal Work. (Note.) G. L. Addenbrooke. "Anne Insulator." *Lond. Elec. Rev.*, March 16, p. 304.

Numbering Conductors, *Lond. Elecn.*, March 16, p. 507.
System used by the Anglo-Am. Brush E. L. Corporation.

Gas into Electricity, *Prac. Elec.*, March, p. 187.

The Relative Cost of Gas, Oil and Electricity. (Note.) *Eng.*, March 23, p. 297.

Gas and Electricity. *Md. Lt. & Ht.*, March 1, p. 250.
Meeting of the New Eng. Assn. of Gas Engrs.

DYNAMOS, SYSTEMS OF DISTRIBUTION, &c.

The Blakey-Emmott Dynamo. (Ill.) *Lond. Elec. Engr.*, March 2, p. 200.

A New Dynamo. *N. Y. Elec. Rev.*, March 17, p. 8. (J. J. Wood.)

New American Electric Dynamo. *West. Elecn.*, March 17, p. 141.

The Fowler-Lancaster Dynamo. (Ill.) *Lond. Elec. Engr.*, March 30, p. 302.

The Silvey Dynamo and Motor. (Ill.) *Elec. World*, March 10, p. 125.

Eickemeyer's Dynamo. (Ill.) *Lond. Elec. Rev.*, March 23, p. 310; *N. Y. Elec. Engr.*, Mach, p. 84. (The "Ironclad.")

The Crompton-Swinburne Dynamo. (Corr.) *Lond. Elec. Rev.*, March 2, p. 247.

Combined Engine and Dynamo at Ordnance Survey, Dublin. *Eng.; N. Y. Elec. Rev.*, March 24, p. 2.

Dynamo Tenders' Hand-Book. (Ill.) Part I. F. B. Badt. *West. Elecn.*, March 17, p. 136. Part II., March 24, p. 148. Part III., March 31, p. 160.

The Term "Magnetic Resistance." (Corr.) Jas. Swinburne. *Lond. Elecn.*, March 9, p. 484.

An Experimental Method of Finding the Work Expended in Establishing a Magnetic Field. *Comptes Rendus. Lond. Elecn.*, March 2, p. 441.

Built-Up Dynamo Plants. (Ill.) S. P. Van Nort. *Elec. World*, March 31, p. 160.

Relative Position of Shunt and Series Coils on Compound Dynamos. (Corr.) "D. W." *Elec. World*, March 17, p. 136.

The Slattery Alternating Dynamo. (Ill.) *Lond. Elec. Engr.*, March 2, p. 208.

The Slattery Induction System. (Ill.) *West. Elecn.; N. Y. Elec. Engr.*, March, p. 114.

Shallenberger's System of Street Lighting by Alternating Currents. Fred. Darlington. *Lond. Elecn.*, March 2, p. 453.

M. Jablochkoff's Transformers. (Ill.) *Lond. Elecn.*, March 9, p. 480.

Electrical Converter. (Ill.) *N. Y. Elec. Rev.*, March 3, p. 8. (E. N. Dickerson, Jr.)

A patented system for obtaining an alternating low tension current from a direct high tension current.

Current Distribution of the Near Future. Dr. Louis Duncan. *Lond. Elec. Engr.*, March 2, p. 207.

Notes on Alternate Currents. J. A. Fleming (continued from p. 406). (Ill.) *Lond. Elecn*, March 16, p. 502.

Transformers or Accumulators? *Lond. Elec. Engr.*, March 2, p. 198.

The Battle of the Transformers. *Lond. Elecn.*, March 2, p. 446.

Alternating Currents in Contiguous Wires. (Corr.) A. G. Holcombe. *Elec. World*, March 10, p. 124.

Primary and Secondary Currents in Induction Coils. *Science*, March 2, p. 105.

Safety Devices with Transformers. (Corr.) Elihu Thomson. *Lond. Elecn.*, March 16, p. 520.

The Measurement of the Power Supplied to the Primary Coil of a Transformer. (Ill.) E. C. Rimington. Phys. Soc. *Lond. Elecn.*, March 23, p. 554; *Eng.*, March 16, p. 271.

On the Measurement of Magnetic Lag. Thos. H. Blakesley. (Corr.) *Lond. Elecn.*, March 9, p. 482. The Lag in Transformers. W. E. Ayrton & John Perry. *Lond. Elecn.*, March 16, p. 509.

The Counter-Electro-Motive Force of Transformers, or Converters. *Md. Lt. & Ht.*, March 15, p. 302.

Experiments on Induction Coils. (Ill.,) Dr. Louis Duncan, Cary T. Hutchinson and Gilbert Wilkes. *Elec. World*, March 31, p. 160.

Formulæ for Transformers. Prof. Geo. Forbes, Soc. of Tel. Engrs. and Elecns. *Lond. Elec. Engr.*, March 2, p. 202.

Electrical Transformers. (Corr.) Emilio Magatti. *Eng.*, March 23, p. 285.

On the Difference of Phases of Currents, on the Retardation of Induction and on the Dissipation of Energy in Transformers: Experimental and Theoretical Researches. Prof. Galileo Ferraris. (Continued from p. 192.) *Lond. Elec. Rev.*, March 2, p. 220; March 9, p. 252. (Concluded.)

Proposed Method of Rendering Retardation of Phase Visible. L. R. Wilberforce. *Lond. Elecn.*, March 23, p. 553.

Alternating vs. Continuous Currents. M. M. M. Slattery, Chic. Elec. Club. *West. Elecn.*, March 24, p. 152. (Corr.) T. Carpenter Smith, March 24, p. 154; H. Ward Leonard, *N. Y. Elec. Rev.*, March 17, p. 4; *N. Y. Elec. Rev.* March 24, pp. 2, 10; *Lond. Elec. Engr.*, March 30, p. 305; *Md. Lt. & Ht.*, March 29, p. 360.

The Comparative Value of the Continuous and the Alternating Current Systems for the Commercial Distribution of Electricity. (Ill.) H. Ward Leonard, Chic. Elec. Club. *Elec. World*, March 24, p. 152; *Prac. Elec.*, March, p. 188.

The Distribution of Electricity by Alternate Currents. (Ill.) T. Carpenter Smith, Nat. Elec. Lt. Assn. *Elec. World*, March 3, p. 113; *Lond. Elecn.*, March 23, p. 546; *Md. Lt. & Ht.*, March 1, p. 222; *N. Y. Elec. Engr.*, March, p. 103; *N. Y. Elec. Rev.*, March 3, p. 12; *Lond. Elec. Engr.*, March 23, p. 284.

The Energy of Alternating Currents. (Ill.) O. B. Shallenberger, Nat. Elec. Lt. Assn. *Elec. World*, March 3, p. 114; *Md. Lt & Ht.*, March 8, p. 277; *N. Y. Elec. Engr.*, March, p. 101; *N. Y. Elec. Rev.*, March 17, p. 10.

On Alternate Current Transformers, with Special Reference to the Best Proportion between Iron and Copper. (Ill.) Gisbert Kapp, Soc. Tel. Engrs. and Elecns. *Elec. World*, March 17, p. 139.

The Distribution of Electricity by Means of Secondary Generators or Transformers. J. K. D. Mackenzie, Soc. Tel. Engrs. and Elecns. *Elec. World*, March 24, p. 154; *West. Elecn.*, March 10, p. 122; March 17, p. 135.

Alternate Current Transformers. (Ill.) *Elec. World*, March 24, p. 153. Discussion of the Kapp and Mackenzie papers before the Soc. Tel. Engrs. and Elecns.

Alternate Current Transformers. Soc. Tel. Engrs. and Elecns. *Lond. Elec. Rev.*, March 2, p. 238; March 9, p. 272; (Note.) March 23, p. 321; *Lond. Elec. Engr.*, March 9, p. 233; March 16, p. 259; (Corr.) E. Manville, March 23, p. 278; March 30, p. 308; *Eng.*, March 9, p. 244; *Indust.*, March 2, p. 224. (Corr.) E. Manville. March 30, p. 325; *Science*, March 23, p. 141; March 30, p. 155.

ELECTRIC POWER.

The Wells Machine for Cleaning Horses. (Ill.) *N. Y. Elec. Rev.*, March 10, p. 10. (Showing use of Sprague Motor.)

Electric Transmission of Power. *Sci. Am. Supp.*, March 3, p. 10,142. The Kriegstetten and Solothurn installation and results of report thereon, with tables of results.

Fire Engines Operated by Electricity. *Jewelry News; Sci. Am.*, March 3, p. 137

Simple Electric Motor. (Ill.) Geo. M. Hopkins. *Sci. Am.*, March 17, p. 165. *Lond. Elec. Engr.*, March 30, p. 296.

Electric Motors. F. L. Pope. *Scribner's Mag.; Lond. Elec. Engr.*, March 23, p. 281.

Glass Cutting by Electricity. (Note.) *Lond. Elec. Rev.*, March 30, p. 345.

Pumping in Mines by Electricity. *Lond. Elec. Rev.*, March 30, p. 339; *Lond. Elecn.*, March 30, p. 565; *Lond. Elec. Engr.*, March 30, p. 298; *Indust.*, March 30, p. 326.

Electric Motors. G. A. Liebig, Jr., Nat. Elec. Lt. Assn. *Md. Lt. & Ht.*, March 1, p. 203; *Elec. World*, March 3, p. 106; *N. Y. Elec. Engr.*, March, p. 105; *N. Y. Elec. Rev.*, March 3, p. 9; *Lond. Elec. Engr.*, March 16, p. 254.

New C. & C. Shunt Wound Motor. (Ill.) *Elec. World*, March 10, p. 125.

The "Belding" Motor. (Ill.) *Elec. World*, March 10, p. 127.

Electric Motors for Organs and Launches. (Ill.) *Elec. World*, March 17, p. 137. (Shows use of small "C. & C." motors.)

Reversing Electric Motors. (Corr.) *Elec. World*, March 24, p. 154.

Transmission of Power in Madrid. *El Economista; Elec. World*, March 17, p. 137; *Lond. Elec. Rev*, March 2, p. 231.

Electric Launches at the Boat Race. *Lond. Elecn.*, March 30, p. 568.

Designing Electric Motors. Fred. Walker. *Prac. Elec.*, March, p. 183. Article awarded the prize by the *Mechanical World*, London.

The Efficiency of Small Electric Motors. E. H. Clifford. Abstract of Paper from *Proceedings* of Am. Academy Arts and Sciences. *Jour. Ins. Civ. Engrs.; Lond. Elec. Engr.*, March 16, p. 250.

Alternating Current Electro-Motors. Dr. Louis Duncan, Am. Ins. Elec. Engrs. *Lond. Elecn.*, March 9, p. 471; *Md. Lt. & Ht.*, March 8, p. 280; *N. Y. Elec. Engr.*, March, pp. 85, 121; *Lond. Elec. Engr.*, March 9, p. 231; March 16, p. 257.

Electric Tramways. R. W. Blackwell. *St. Ry. Jour.*, March, p. 70.

The Bentley-Knight Electric Railway. (Ill.) *St. Ry. Jour.*, March, p. 63.

The Bentley-Knight System at Allegheny, Pa. *N. Y. Elec. Rev.*, March 3, p. 1.

The Bentley-Knight Tramway System. (Ill.) *Lond. Elec. Engr.*, March 9, p. 225.

Electrical Traction. *Science*; March 23, p. 141; *Prac. Elec*, March, p. 187.

Electric Traction. (Ed.) *Lond. Elec. Rev.*, March 30, p. 329. (Note.) Edward Manville. March 23, p. 326.

Schlesinger Electric Locomotive Motor. (Ill.) *Lond. Elec. Engr.*, March 9, p. 222.

Electro-Magnetic Traction Increasing Apparatus. (Ill.) *West. Elecn.*, March 31, p. 158.

The Hannah's Elevated Railway. (Ill.) *West. Elecn.*, March 3, p. 110.

New Switch on the Julien Electric Car. (Ill.) *Elec. World*, March 31, p. 161.

The Frankfurt-Offenbach Electric Tramway. (Ill.) E. Krause. *Lond. Elecn.*, March 23, p. 533.

An admirably full and detailed description of the road, which is operated on the overhead system with slotted tube conductors.

Electric Traction—Closed Conduit Systems. (Corr.) W. Geipel. *Lond Elecn.*, March 9, p. 482. Lond. Ins. Civ. Engrs. *West. Elecn.*, March 31, p. 164.

Electric Tramways with Stationary Metallic Conductors. R. W. Blackwell. *Lond. Elec. Engr.*, March 23, p. 279.

Electrical Street Railways. (Corr.) "Engineer." *N. Y. Elec Rev.*, March 3, p. 10.

Underground Haulage by Electricity. (Ill.) *Sci. Am. Supp.*, March 31, p 10,211.

Wm. Geipel's paper on application of electric railways to mine work.

The Electro-Automatic Transit Company of Baltimore. (Ill.) *N. Y. Elec. Rev.*, March 10, p. 8.

For carrying packages across the country by electric express.

INSTRUMENTS, MEASUREMENTS, &c.

Elementary Testing Suitable for Electric Lighting Systems. (Ill.) Thomas Gray. *Lond. Elec. Engr.*, (cont'd from p. 129,) March 2, p. 199; March 16, p. 246; March 30, p. 294.

Letters for Learners and Unprofessional Readers. (Ill.) H. D. Wilkinson. *Lond. Elecn.*, March 2, p. 438; March 9, p. 477; March 16, p. 504; March 23, p. 543; March 30, p. 566. Chap. VIII. The Calibration of Current Indicators.

"Le Wattmetre et son Maniement." (Review.) *Lond. Elecn.*, March 16, p. 506.

"The Percentage Accuracy of Wattmeters." (Corr.) L. R. Wilberforce. March 30, p. 580.

Instruments of Precision of the Mather Electric Company. (Ill.) *Elec. World*, March 24, p. 149.

New resistance box, bridge and galvanometer devised by Prof. W. A. Anthony.

The Last Model of the Aron Electric Meter. *Sci. Am. Supp.*, March 10, p. 10,160.

Western Electric Co's Electric Current Indicator. (Ill.) *N. Y. Elec. Rev.*, March 3, p. 1.

The Sesemann Ammeter. (Note.) *Lond. Elec. Engr.*, March 2, p. 195.

Application of the Deci-Ampere or Centi-Ampere Balance to the Determination of the E. M. F. of Voltaic Cells. *N. Y. Elec. Rev.*, March 31, p. 1.

Combined Galvanometer, Ammeter and Voltmeter. (Ill.) *West. Elecn.*, March 24, p. 146.

Portable Voltmeters for Measuring Alternating Potential Differences. W. E. Ayrton and John Perry, Soc. Tel. Engrs. and Elecns. (Concluded.) *Elec. World*, March 10, p. 128.

A New Pattern of Reflecting Galvanometer with Lamp and Scale. (Ill.) G. L. Addenbrooke, Phys. Soc. *Lond. Elec. Rev.*, March 16, p. 289; *Lond. Elecn.*, March 16, p. 517; *Eng.*, March 16, p. 271; *Indust.*, March 23, p. 304.

Modern Telegraph Galvanometers. W. Moon. *Lond. Elec. Rev.*, March 9, p. 253.

A Mechanical Temperature Compensation for the Bifilar Magnetometer. "G. W. T." *Lond. Elecn.*, March 23, p. 545.

The Unit of Resistance. (Corr.) "E. R. R." *Elec. World*, March 31, p. 168.

Practical Electrical Units. W. B. Esson. (Cont'd from p. 153.) *Lond. Elec. Engr.*, March 9, p. 222.

Queries as to Calculations. (Corr.) H. E. *Elec. World*, March 10, p. 122.

The Notation of Magnetic Quantities. (Corr.) E. Hospitalier. *Lond. Elecn.*, March 2, p. 451.

Wire Tables. *Md. Lt. & Ht.*, March 1, p. 177.

Harcourt's New Pentane Standard Lamp. (Ill.) *Lond. Elecn.*, March 2, p. 456; *Lond. Elec Engr.*, March 2, p. 212; *Elec. World*, March 10, p. 127.

Von Hefner Alteneck's Amyl Acetate Standard of Light. *Elek Zeits.; N. Y. Elec. Rev.* March 31, p. 10.

Standards of Length and their Practical Application. Geo. M. Bond, Soc. of Arts. *Md. Lt. & Ht.*, March 22, p. 329; March 29, p. 354

The Radio Micrometer. (Note.) *N. Y. Elec. Rev.*, March 24, p. 5.

UNDERGROUND WIRES.

Underground Conductors. (Ed.) *N. Y. Elec. Engr.; Lond. Elec. Rev.* March 23, p. 305.

The Brooks System. (Note.) *Lond. Elec. Rev.*, March 23, p. 327. David Brooks. (Ill.) p. 328.

The Undergrounding of Electric Arc Light Wires. W. W. Leggett, Nat. Elec. Lt. Assn. *Md. Lt. & Ht.*,, March 8, p. 272; *N. Y. Elec. Engr.*, March, p. 91; *N. Y. Elec. Rev.*, March 3, pp. 4, 8; *Lond. Elec. Engr.*, March 30, p. 304; *Elec. World*, March 3, p. 115.

Underground Conductors for Electric Currents. Nat Elec. Lt Assn. Jesse M. Smith. *Elec. World*, March 3, p. 116; *Md. Lt. & Ht.*, March 1, p. 224; *N. Y. Elec. Engr.*, March, p. 94; *N. Y. Elec. Rev.*, March 3, p. 10.

Methods of Protecting Ends and Splices of Underground Cables. (Ill.) W. R. Patterson. *West. Elecn.*, March 10, p. 12..

Underground Wires for Boston. *Md. Lt. & Ht.*, March 22, p. 326. Public hearing. Testimony of experts.

Underground Electric Light Wires. *Elec. World; Indust.*, March 16, p. 272. (Corr.) Frank Brewer. March 23, p. 300; March 30, p. 330.

THERMO-ELECTRICITY.

E. Raub's New Thermo-Electric Battery. G. Betz. *Lond. Elec. Rev.*, March 30, p. 332.

The Temperature at which Nickel Begins Suddenly to Lose its Magnetic Properties. (Corr.) Herbert Tomlinson. *Lond. Elecn.*, March 16, p 520; *Lond. Elec. Rev.*, March 9, p. 277. (Phys. Soc.) *Eng.*, March 2, p. 223.

Thermo-Magnetic Motor. (Ill.) *Sci. Am. Supp.*, March 10, p. 10,160. W. B. Cooper, Inventor.

On Some Early Forms of Electric Furnaces. (No. 2, Depretz's Electric Furnaces.) Edwin J. Houston. *Jour. Fkln. Inst.*, Feb., p. 127.

MECHANICAL, &c.

Compound "Robey" Engine. (Ill.) *Lond. Elec. Engr.*, March 2, p. 201.

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Paillard's Non-Magnetic Compensating Balance and Hair-Spring for Watches. Prof. Edwin J. Houston. *Prac. Elec.*, March, p. 179. (Ill.) *Jour. Fkln. Inst.*

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Improved Primary Battery. (Ill.) *Sci. Am. Supp.*, March 17, p. 10175. (P. Selby.)

The Schanschieff Primary Battery. *Elec. World*, March 31, p. 167.

The New "Law" Battery. (Ill.) *Elec. World*, March 31, p. 168.

A Novel Form of Primary Battery. (Ill.) *Elec. World*, March 31, p. 168.

The Woodward battery, in one form of which the positive electrode consists of zinc sponge, and the negative consists of a piece of iron, around which is placed a jacket of perforated iron, the space between the casing and the piece being filled with oxide of copper and iron filings or turnings. The electrode is placed in a caustic potash solution.

Oxide of Copper Battery for Incandescent Lighting. (Corr.) "H. M." *Elec. World*, March 24, p. 148.

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Exemplifies process for the retention of the active material in capsules rolled and clinched into the plates.

The Carrière Accumulator. *Elec. World*, March 24, p. 150.

Carbon plates having grooved or corrugated surface coated with a composition made by mixing litharge with dilute sulphuric acid containing one-tenth of the strong acid.

Starting the Dynamo On to the Accumulators. (Ill. Note.) T. W. W. Melhuish. *Lond. Elecn*, March 2, p. 451.

Experiments with Accumulators. *Elek. Zeits.; N. Y. Elec. Rev.*, March 31, p. 1.

Results with Huber accumulators, which gave an efficiency in ampere hours of 90.7 per cent., or, in total electrical work, 78.4 per cent.

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Dr. S. P. Thompson at Royal Vic Hall.

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An ingenious "vice-grip" split tube coupling devised by Carl Hering.

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Report of and notes upon the paper read before the Ins. of Mech. Engrs, by Wm. Geipel.

A Novel Electro-Magnet. *Jour. Fkln. Inst.*, March, p. 262.

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Method of throwing open or closing doors by means of electro-magnets connected with thermostats. An alarm annunciator is placed in the circuit, if desired.

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NAME.	ABBREVIATION.	PUBLISHED, &c.
Engineer.	*Engr.*	London, 163 Strand, weekly. £1.9.
Engineering.	*Eng.*	London, 35–36 Bedford St W, C.; weekly. £1.16.
Industries.	*Indust.*	Manchester, 70 Market St., weekly. £1.12.
The Electrician.	*Lond. Elecn.*	London, 1 Salisbury Court, E. C.; weekly. £1.2.
The Telegraphic Journal and Electrical Review.	*Lond. Elec. Rev.*	London, 22 Paternoster Row, E. C.; weekly. £1.1.8.
The Electrical Engineer.	*Lond. Elec. Engr.*	London, 139–140 Salisbury Court; monthly. 3d. per issue.
The Telegraphist.	*Telegraphist.*	London, 74–76 Great Queen St., W. C.; monthly, 2d. per issue.
Nature.	*Nat.*	London, 29 Bedford St., W. C.; weekly, £1.8.
Knowledge.	*Knowledge.*	London, 39 Paternoster Row; monthly, 6d. per issue.
India Rubber & Gutta Percha & Electrical Trades Journal.	*I. R. & G. P. Jour.*	London, 115 Finsbury Pavement, E. C; monthly. 15 shillings.
The Electrical Engineer.	*N. Y. Elec. Engr.*	New York, 11 Wall Street; monthly, $3
The Electrical World.	*Elec. World.*	New York, 168–177 Potter Building; weekly. $3
The Electrical Review.	*N. Y. Elec. Rev.*	New York, 13 Park Row; weekly. $3.
The Electric Age.	*Elec. Age.*	New York, 5 Dey Street; semi-monthly, $1.50.
Modern Light and Heat.	*Md Lt. and Ht.*	Boston, 178 Devonshire St.; weekly, $3.
Western Electrician.	*West. Elecn.*	Chicago, 6 Lakeside Building; weekly, $3.
Journal of the Franklin Institute.	*Jour. Fkln. Inst.*	Philadelphia, Franklin Institute; monthly, $5.
Science.	*Science.*	New York, 47 Lafayette Place, weekly, $3.50.
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Mechanics.	*Mech.*	Philadelphia, 907 Arch St.; monthly, $1.
Railroad Gazette.	*R'd. Gaz.*	New York, 73 Broadway; weekly, $4 20.
American Machinist.	*Am. Mach.*	New York, 96 Fulton St.; weekly, $2.50.
Street Railway Journal.	*St. Ry. Jour.*	New York, 113 Liberty St.; monthly, $2.
Street Railway Gazette.	*St. Ry. Gaz.*	Chicago, 9 Lakeside Building; monthly, $2.
Light, Heat and Power.	*Lt. Ht. and Pr.*	Philadelphia, 413 Walnut Street; semi-monthly, $3.
Progressive Age.	*Prog. Age.*	Philadelphia, 333 Walnut St.; monthly, $2.
Railroad and Engineering Journal.	*Rd. and Eng. Jour.*	New York, 45 Broadway; monthly, $3.
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"Every man is a debtor to his profession, from the which, as men do of course seek to receive countenance and profit, so ought they of duty to endeavor themselves, by way of amends, to be a help thereunto."

LORD BACON.